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The impacts of high frequency pulse driving on the performance of LED light

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Abstract

Due to the high lighting efficiency and long lifecycle, the light-emitting diode (LED) plays a major role in the green earth activities; energy saving and carbon offset. Since the LED lights have the better energy efficiency, they have gradually become the major source of LCD backlight. The luminance of LED light source must be adjusted suitably when used for the backlight source or lighting, therefore, the pulse wave modulation (PWM) is a commonly used technique for the LED light modulation. However, when the LED is applied to the field sequential color LCD for a long time, the trigger pulse will readily affect the LED light performance. This paper presents the impacts of PWM driving on the performances of LED; color temperature, luminance efficiency and lifecycle.

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1. Introduction

In the early development, the LED was limited by its material and fabrication technology, the improvement of its output power was very slow. Consequently, it can only apply to status display. In the recently, the kinds of LED and output power have significant improvement. In the earliest, the LED only have red light with 0.01W. Now, the LED has red, green, blue, white, UV and IR etc. And the power of some special LED is improved to 100W.

The most LED research was based on the direct current (DC) power. But the most equipment of electric power generation produces alternating current (AC) power. Therefore, many studies focused on how to improve the power efficiency in the AC system. In the recent 10 years, the display has changed from the CRT to TFT-LCD. In the LCD display technology, the red, green and blue (RGB) light source was split from the white light by optical filter. In this method, the light needs more power to improve its intensity. Consequently, some researches decides to drive the RGB LED directly, and used time shift method to turn on the single color LED. Due to the persistence of human

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vision, the human can still feel the image is full color. Because of the absence of optical filter, so the light intensity increase over 30% with the same driven power. It can benefit to the energy saving and carbon offset.

When the LED is applied to lighting application, it have some insufficient because its characteristic is single wavelength and unstable light intensity. In the lighting application, the color temperature, light intensity adjustment and color rending property are important application condition. Many studies said the lighting property affect the psychology and physiology of human. For example, the warm color light let the user feels relaxed and warm, and the cold color light let the user be able to concentrate his attention. In lighting application, low light intensity will result in the object profile is blur for vision, high light intensity will result in the object detail can not be recognized. Therefore the light intensity must be appropiate adjusted. Consequently, many studies present the different wavelength LED and light intensity adjustment method, which the lighting device his high color rending property, fine color temperature and fine light intensity.

All LEDs application require the light adjustment functions. The most digital LED light adjustment method, the pulse width modulation (PWM) and pulse frequency modulation (PFM) are required. The PWM and PFM need to operate the pulse driven current for a long time. Therefore, this paper will show the effect of pulse driven method for LED color temperature, lighting efficiency.

2. Principle of LED modulation method

The working current stands for movement velocity of electric hole and electric. The combined probability and times will increase between the 2 carriers when increase the working current by the modulation technology. And the emitted energy and light intensity will increase with the energy increasing.

If the light intensity modulated procedure need to consider the value of color coordinate x and y (CIE 1931), the light intensity adjustment can use the analog voltage to change the electric field of PN material. The different electronic field will change the material energy band and the photon energy level . Then they will result in the color variation.

In the LED modulation method, the electronic filed of PN material must fixed. And the modulation method adjusts the light intensity through change the current. The common digital light modulation methods are PWM and PFM. The schematic PWM and PFM, shown in the Fig. 1 and 2.

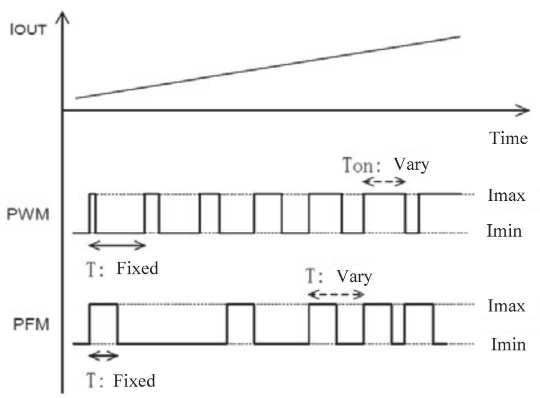

Figure 1 schematic of PWM and PFM

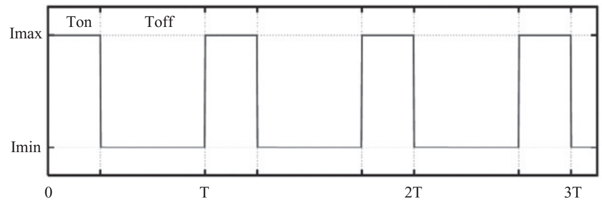

Figure 2 Schematic diagram for PWM and PFM parameters

2.1 Pulse Width Modulation (PWM)

The PWM method fixes the working frequency and change the average current by changing the time widths ratio of rectangular pulse (T_{on} and T_{off}), expressed as the Eq. (1). In the LED light modulation application, $I_{\min}=0$ and $T_{on}+T_{off}=T$. The Eq. (1) can be modified to Eq. (2). It is able to increase the passed average current in the LED significantly, and obtain better light modulation performance.

$$I_{avg}=I_{max}\times\frac{T_{on}}{T_{on}+T_{off}}+I_{min}\times\frac{T_{off}}{T_{on}+T_{off}} \tag{1}$$

$$I_{avg}=I_{max}\times\frac{T_{on}}{T}=I_{max}\times(duty\_cycle)\ \% \tag{2}$$

2.2 Pulse Frequency Modulation (PFM)

From PFM method, the time width T_{on} is fixed, the average current can be changed by adjusting the working frequency, expressd as the Eq.(3). The amplitude and time width of the passed rectangular pulse current is fixed. The working frequency changes with according to the user need. In the LED light modulation , $I_{\min}$ is zero and T_{on} is constant, the I_{avg} can be modified to Eq.(3). It is able to increase the passed average current on the LED significantly, and obtain better light modulation performance. But this method will result in the flick when the working frequency is low.

$$I_{avg}=I_{max}\times\frac{C}{C+T_{off}}=I_{max}\times(duty\_cycle)\ \% \tag{3}$$

The above PWM and PFM methods can change the average working current of LED, but considering the practicability and circuit achievement, the following experiments will use the PWM method.

3. Experimental scheme

3.1 Input power of LED

In the DC LED driven circuit, the input power is the voltage of LED multiple the average current which is controlled by the PWM. The power of LED is

$$W_{LED}=V\times I=V_f\times I_{avg} \tag{4}$$

Because $I_{avg} = I_{max} \times T_{on}/T$, the Eq. (4) can be modified to

$$W_{LED} = V_f \times I_{max} \times \frac{T_{on}}{T} \tag{5}$$

where is forward bias of a diode, is cycle time. In the subsequent section, this paper will discuss the effect of light propriety with different driven method.

3.2 Driven waveform

In this experiment, the colors of tested LEDs are red, blue and green respectively. From Eq.(5), for fixed input power, the different and sets are existed. Therefore, this paper uses the different sets to drive the LED. Then this paper will discuss the effect for lighting property by the different driven method in the subsequent. The sets shown in the Table 1.

Table 1 PWM modulation parameters

	$I_{\max}$	T	Duty cycle
State 1	30 mA	2 ms	20 %, 40 %, 80 %, 100 %
State 2	100 mA	1 ms	20 %, 40 %, 60 %, 80 %
State 3	200 mA	0.5 ms	20 %, 40 %, 60 %, 80 %

3.3 Design of the LED driven circuit and scheme of the optical measurement system

We control the LED ON/OFF to trigger the field-effect transistor by using the signal generator, the driven circuit as shown in the Fig. 3. Because of the power supply supports a fixed voltage. The LED working current can be expressed as the following

$$I_{\max} = \frac{(V_{CC} - V_f)}{R} \tag{6}.$$

The specification of optical measurement system and environment parameters is shown in the table 2.

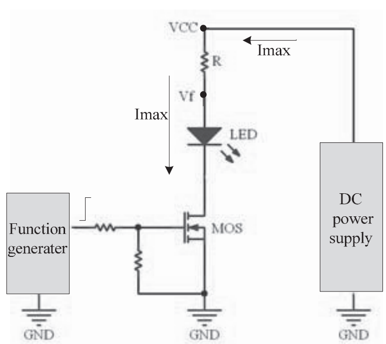

Figure 3 Schematic of LED driven circuit.

Table 2. Specification of LED light measurement system

Instrument	PHOTO RESEARCH PR-670
Measurement distance	35 cm
Field of view	0.125 degree
Unit of brightness	cd/m2 (nits)
Temperature	21.9 ℃
Relative humidity	51.8 %

4. Experimental results and discussion

4.1 Variation of CIE value

When the I_{max} is 30mA, the CIE value of LED light is stable by PWM. The coordinate value of red light LED is (0.695, 0.305). The coordinate value of green light LED is (0.13, 0.7). The coordinate value of blue light LED is (0.13, 0.06).

With the increment of pulse current, the CIE coordinate value distribution of the 3 color LED are disperse gradually, although the average working current is down by using PWM method to change time width T_{ON}. The coordinate value cannot be keeped at $I_{max} = 30$ mA. Figure 4, 5 and 6 show the experimental result for red, green, and blue LED respectively.

From the experiment results, when the working current of red light LED increases, the x, y coordinate value drift form standard value to M. When the working current is over the rated current, the color temperature of green LED will be change. Form the Fig. 5, the coordinate value of LED is change to (0.11, 0.32) when I_{max} is 100 mA. For more working current, this status will more obviously. The status of color temperature distribution of blue light LED is similar to the green light LED when the working current is below 100mA. But the color temperature distribution will disperse seriously when the working current is higher.

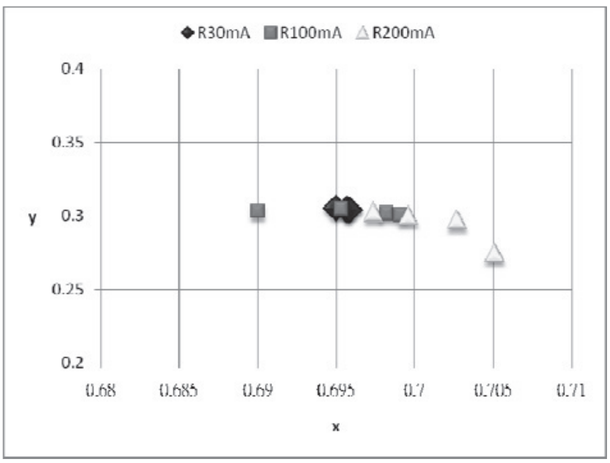

Figure 4 CIE measurment result of red light LED

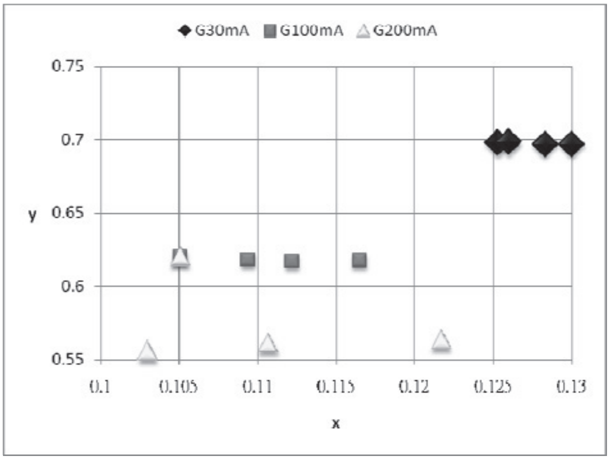

Figure 5 CIE measurment result of green light LED

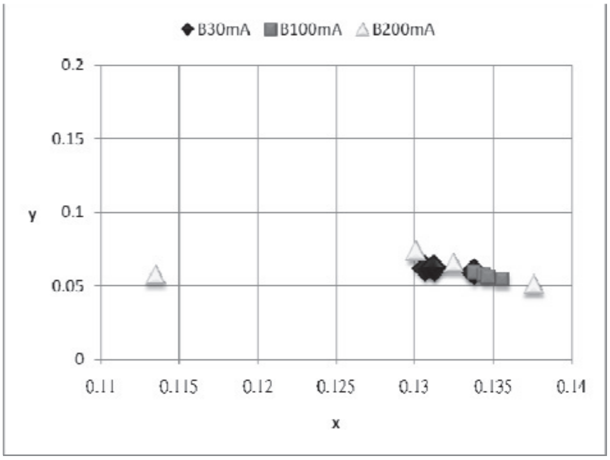

Figure 6 CIE measurment result of blue light LED

4.2 Light efficiency (relationship between the brightness and average current)

From the experimental results, different driven methods affect the lighting efficiency significantly. Fig. 7, 8, and 9 show the experimental results of lighting efficiency. When the rated current is 30mA, the red light LED shows the nonlinear light modulation phenomenon, and the green light LED and blue light LED show the nonlinear brightness variation. When the working current of test target reaches 100mA or 200mA, the LED still can obtain the same average input power through PWM modulation method. But for higher working current, the lighting efficiency of red light LED decays slowly. It means the red light LED has high tolerance and its performance can maintain close to the original when the transient working current is large. But the lighting efficiency of green light LED and blue light LED decay very fast when the working current diverge the original design current (30mA).

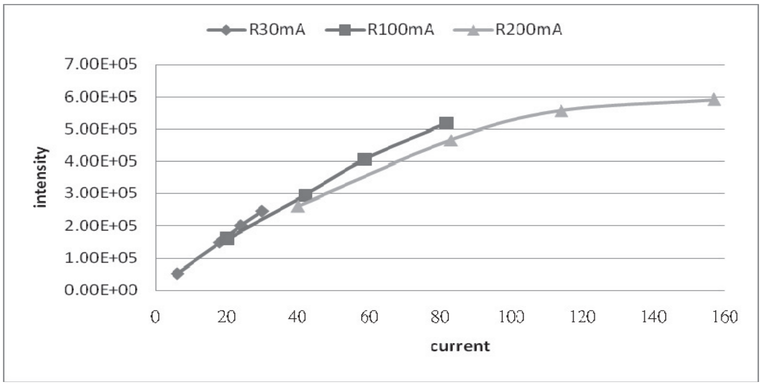

Figure 7 lighting eficiency test resul of red light LED

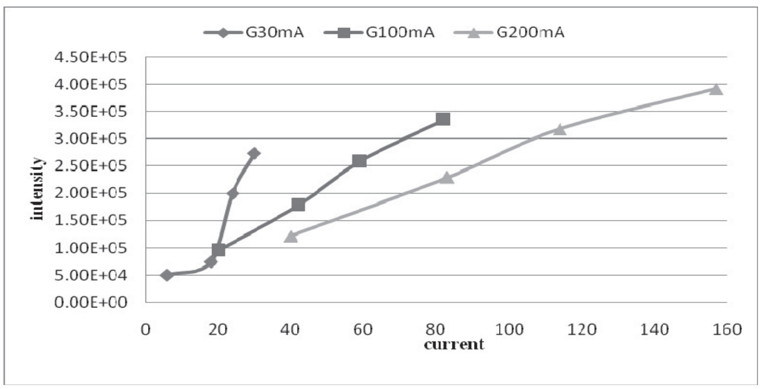

Figure 8 lighting eficiency test resul of green light LED

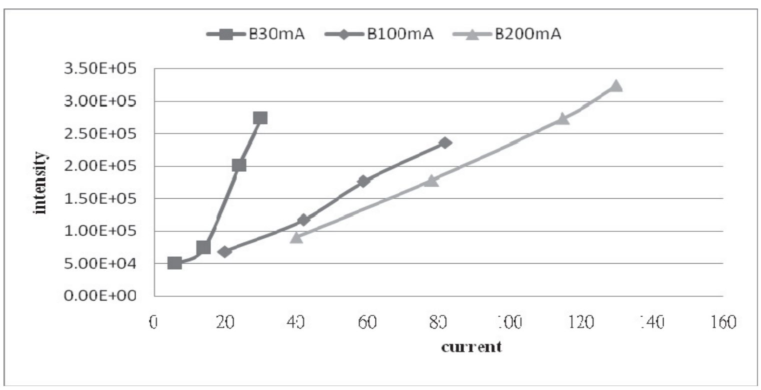

Figure 9 lighting eficiency test resul of blue light LED

5. Conclusion

Compare to traditional concept, the control device can obtain the same average power and performance. That is similar to original when using PWM modulation method to other device (ex. motor). But the transient response of LED is acute, it results its performance change. From the experiments, the I_{max} and T in the driven circuit of 3 original color light should be considered comprehensively for the backlight source or lighting. It will affect the lighting efficiency and color temperature of LED.

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Reference

1. Y.H. Fan et al, , The 9th Joint Conference on Information Sciences （JCIS）, Taiwan, (2006) 8–11.
2. T.F. Pan, H.J. Chiu, S J. Cheng, and S.Y. Chyng, The 8th International Conference on Electronic Measurement and Instruments, Vol. 4 (2007). 212- 215.
3. E. Mineiro Sa, C.S. Postiglione, R.S. Santiago, F. Antunes, and A.J. Perin, IEEE Proc. ECCE, (2009) 2827-2832.
4. E. Mineiro Sa, C.S. Postiglione, R.S. Santiago, F. Antunes, and A.J. Perin, IEEE Proc. ECCE, (2009) 2827-2832.
5. W.K. Lun, K.H. Loo, and S.C. Tan, IEEE Trans. Power Electron., vol. 24 (2009) 2920-2932.
6. D.G. Lamar, J.S. Zuniga, A.R. Alonso, M.R.Gonzalez, and M.M. H. Alvarez, IEEE Trans. Power Electron., (2009) 2032-2042.
7. L. Gu, X. Ruan, M. Xu, and K. Yao, IEEE Trans. Power Electron., vol. 24 (2009) 1399-1408.
8. Z.M. Ye, F. Greenfeld and Z.X. Liang, Power Electronics Specialists Conference, 2008. PESC 2008., (2008) 2657-2663.
9. P.Y. Sam, H.H. Joo, K.H. Suk, P.J. Kyu and J.Y. June, United States Patent No. 7321137 (2008).
10. G. Harbers, L. Scheffel, M.H. Keuper and R.H. Holman, United States Patent No. 7494228 B2 (2009).
11. T. Uchida, K. Saitoh, T. Miyasita and M. Suzuki, Proc. 17th IDRC, (1997) 37-40.
12. F. Yamada, et al., Journal of Info. Display, Vol. 10 (2002) 81-85.
13. T. Fukami, et al., IDW'06, (2006) 1617-1620.
14. C.C. Chen, C.Y. Wu, P.C. Lu, Y.M. Chen and T.F. Wu, Proc. of IEEE Power Electronics and Motion Control Conference, Vol.1 (2006) 1-5.
15. T. F. Wu, C. C. Chen, C. Y. Wu, P. C. Lu and Y. R. Chen, Proc. of IEEE Power Electronics Specialists Conference, 17-21 (2007) 2947-2952.
16. C.C. Chen, C.Y. Wu and T.F. Wu, Proc. of IEEE Power Electronics Specialists Conference, 18-22 (2006) 1-7.